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Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

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Bernard B. Berger
Chief, Research Branch
Division of Water Supply and Pollution Control
Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

My assignment is to evaluate water quality protection techniques, a formidable task. It requires us to consider the effectiveness of sanitary engineering developments of the last half century and examine sanitary engineering as it is practiced and taught today. This is a large assignment, even in brief.

Actually, the Sanitary Engineering Center should be in a good position to make such an evaluation. We receive requests for technical assistance from all parts of the Nation. Sometimes we can provide the assistance required, but often we cannot. We do not always have the funds and personnel to do the work, but more frequently we just do not have the necessary know-how ourselves. We may thus be considered to be experts in what we should know but do not. I propose to draw fully on this knowledge, or the lack of it, in this evaluation.

What do we consider to be the essential phases of water quality protection? Obviously, they should include more than the treatment of waste and water. In this analysis I shall begin at the point of waste origin and terminate at the point of water use. I propose to discuss in logical fashion the following steps in water quality protection:

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16. Abstracts In an evaluation of water quality protection techniques the following six points are discussed: 1) Accounting for all pollution reaching a body of water; 2) predicting the pollutional effects of a given waste; 3) treating waste to prevent pollution; 4) using the stream effectively and economically in waste disposal; 5) monitoring the receiving stream intelligently and 6) treating contaminated water for reuse economically and effectively. Separating polluting substances from water is a weakness common to most of the basic techniques, especially chemical characterization of complex wastes, in treatment of wastes and water, **and** in monitoring receiving waters. Hence it is recommended that development of new techniques in separating polluting substances from water be undertaken. Of particular interest are developments in modified absorption, chromatography, foam fractionation, freezing, direct solvent extraction and ion exchange.

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1. Accounting for all pollution reaching a body of water.
2. Predicting the pollutional effects of a given waste.
3. Treating waste to prevent pollution.
4. Using the stream effectively and economically in waste disposal.
5. Monitoring the receiving stream intelligently.
6. Treating contaminated water for reuse effectively and economically.

If our mastery of these techniques is complete, we should have no great concern about protecting the quality of the water resource. If not, we should in all common sense determine where our weaknesses lie, and undertake the necessary research to correct them. I shall consider each technique separately.

Do we account for all pollution reaching streams?

When we think of pollution, we normally consider sewage and industrial wastes. This is not surprising. One expects an industrial plant to produce an industrial waste just as a community produces sewage. In recent years we have had to consider the growing pollutional effect of land drainage, particularly that from agricultural lands. More recently we have become aware of pollution resulting from chemical poisons deliberately applied to the water course to kill weeds, insect larvae, fish, and other forms of aquatic life. Even more recently our attention has been directed to motorboat exhaust emissions as a potential troublemaker.

It is pertinent to ask whether our common sampling and analytical procedures permit us to identify and trace the significant components of these wastes. I should like therefore to consider separately each of the avenues through which man-made pollution may reach streams.

1. Sewage is assuming new, important characteristics. For example, organic chemicals of industrial origin are often undetected and unsuspected components of sewage. It is probable that the presence of alkyl benzene sulfonate, the basic ingredient of household synthetic detergent, would be unsuspected if it were not associated with foam. One could speculate on the presence of other substances, equally resistant to treatment and equally persistent in the stream, which give no physical or chemical clues to their identity. Giving point to such speculation is the growing trend toward combined treatment of sewage and industrial waste. It is likely that in the future the waste effluent of each community will be unique because of the industrial substances it contains.
2. It is not necessary to belabor the point that the "traditional" industrial wastes, the dinosaurs of our experience, are still major problems. However, new and perhaps even more troublesome wastes are being encountered. Increasing interest is directed to radioactive wastes from uranium ore refining plants and nuclear power reactors, thermal pollution from power plants and industrial cooling operations, and the vast complex of waste substances discharged by the chemical industries. Synthetic organics are a particular problem because of the very rapid growth of the petrochemical industries. Many of these organic compounds resist destruction by the communities of microorganisms on which we depend for organic waste stabilization in the treatment plant and in the stream. They may persist almost indefinitely in the stream, and reach locations of water use many

miles below the point of waste discharge. An interesting example is a benzene derivative we followed 1000 miles down the Mississippi River. This we found almost by accident. The gap in knowledge of the quantity and character of many industrial wastes is a problem of fundamental importance in the protection of water quality.

3. The increasing use of agricultural poisons, particularly insecticides, is reflected in the appearance of these chemicals in bodies of water receiving farmland drainage. DDT has frequently been recovered from streams, and even from treated water supplies. One of the new chlorinated hydrocarbon insecticides is the most toxic material yet encountered for fish. It has been used in Pennsylvania to destroy rodents in orchards. Like other such substances, it is persistent in water solution and is not easily removed by conventional water treatment processes. Here is a problem to tax those responsible for water quality management: How shall we account for a waste whose source is general land drainage rather than the point source represented by a specific outfall sewer?

4. The growing use of synthetic organic poisons to destroy nuisance water vegetation, mosquito larvae, and undesirable fish has introduced new water quality control problems. Dickinson, North Dakota, provided us with a typical case. To destroy worthless coarse fish prior to restocking with game fish, it was proposed that a fish poison be applied to the municipal raw water impoundment in use. As one would expect, the health authorities were concerned with the ability of the water treatment plant to prevent this material from

reaching the treated water. With the increasing recreational appeal of stored waters, it is clear that problems of this kind will be experienced widely and frequently. Obviously, control can be applied only if it is known that the toxic material has been applied to the water source.

5. It is too early to present a clear picture of the potential problem that could result from the emissions of outbcard motors. It is possible, however, that we will have in the water environment an analogy to the problem of automobile exhaust emissions to the atmosphere.

Having a new waste in hand, can we predict its potential pollutional effects?

Can we confidently predict the effect of the waste on the dissolved oxygen of the stream, its toxic effect on fish and other aquatic life, its tainting effect on fish flesh, its possible damage to water treatment processes, its effect on water palatability, and its harmful effect on persons who drink that water?

I think you will agree that few agencies are presently equipped to do more than estimate the waste's probable effect on the dissolved oxygen of the stream, and to determine, within rough limits, its toxic effect on fish in the receiving water.

Several years ago the Center undertook to evaluate its ability to make such predictions. We selected a group of six organic cyanides as the wastes of challenge. Chemists, engineers, biologists, and toxicologists were assigned to determine the pollutional character of these compounds. They were

instructed to exercise ingenuity wherever standard methods and equipment could not be used. Improvisation was necessary. For example, it was found that conventional organic analysis could not detect nor measure the low concentrations of compounds found to be significant. Quantitative analysis based on fish bioassay solved this particular problem.

Our experience suggests that a well equipped and well staffed laboratory can obtain the information needed to predict a new waste's probable impact on certain important downstream water uses. However, the acid test will come when we match our laboratory results against field findings in an actual problem situation. This we have not yet done.

The laboratory tests constitute an expensive, time-consuming project -- not one to be undertaken as a routine task. The toxicological phase of the study is perhaps its most perplexing aspect. The specialized services and cost necessary for determining the effect of repeated exposure to low concentrations of the waste for long periods of time would inevitably place this job out of reach of most public agencies. Equally discouraging is the probability that the toxicological study may take as long as two years.

Assuming we can determine tolerance levels for this waste, can we really treat it effectively?

Many yardsticks of waste strength and character are in use; Biochemical Oxygen Demand (BOD) is unquestionably the most common. With the best treatment processes available, a BOD reduction of approximately 95% may be obtained. A reduction in BOD does not mean that the objectionable mineral salts -- nitrates and phosphates -- have been removed. Just the opposite effect is

produced in sewage stabilization by secondary treatment. Likewise, the soluble inorganic constituents of wastes are not removed by conventional secondary waste treatment processes. And it has already been noted that many persistent organics discharged in sewage and in chemical industry wastes do not have a BOD. They are either nonoxidizable or they exert their oxygen demand so slowly as to be considered nonoxidizable. Obviously, a reduction in a waste's BOD gives no assurance that such compounds have been removed or destroyed.

We have found that the effluents of biological treatment plants may contain approximately 100 ppm of volatile solids. We may equate these solids to biologically resistant organic substances in solution. We have only a vague idea as to their composition. However, this we can be sure of: we should rather not have them in our drinking water.

The possibility that so-called complete treatment of wastes may not always be sufficient was pointed out by G. E. McCallum, Chief, Division of Water Supply and Pollution Control, Public Health Service, at the 1959 Purdue Industrial Wastes Conference. A new interest has been stimulated in the future's need for tertiary treatment processes and, beyond that, for advanced cleansing of wastes. In passing I should like to say that we look to the field of physical chemistry for important contributions to such research.

In disposal of waste effluents, do we make effective use of the receiving water?

One of the great intellectual satisfactions of the sanitary engineer is the application of the oxygen sag formulation. This application assumes a rapid, efficient mixing of waste and water. Does this really occur? Streaks

of waste may often be traced many miles along a water course. Obviously, the full dilution effect is not being used. This often poses stream sampling problems because of variation in waste concentration in a cross-section of a stream. It also raises pertinent questions regarding the adequacy of outfall design techniques.

Many of you have personal knowledge of the relatively poor state of the art of waste disposal into tidal waters. A profound question is, "What is the fate of a particle of waste discharged into a mass of tidal water?". Every one of the 24 coastal and Gulf States is seeking, or will inevitably seek, effective techniques to answer this question. The use of models to supplement field studies is a recent interesting development.

Having disposed of the waste effluent, can we monitor effectively the quality of waters which have received it?

Until recently, few programs of water quality intelligence would present a realistic picture of changing quality conditions in a stream, and those were usually developed at great expense in special problem situations. You may recall that in December 1955 the unsatisfactory condition regarding knowledge of the quality of water impelled the President's Advisory Committee on Water Resources to recommend that improvement in basic data was urgent. This recommendation sparked the development of the PHS National Water Sampling Network and the parallel systems of State and interstate agencies. In a more remote sense, it led to this symposium in which we are participating.

A great deal of data is now being collected. Perhaps, as a result of the deliberations of this Symposium we will be better able to assess the usefulness of these data.

We believe we are progressing with respect to detection of certain types of pollution. Recent improvements in sampling and analytical techniques for coliform organisms and enterococci permit us to discern fecal contamination more readily than before. The successful development of equipment for continuous recording of dissolved oxygen represents a significant advance in the monitoring of streams for oxygen-demanding wastes. The current emphasis on radioactivity monitoring is providing steadily improved instrumentation for this program. However, many important shortcomings remain.

There is a growing and important need for an improved method of capturing and identifying soluble organic compounds in water. At the present time a carbon filter which was designed and developed by the Sanitary Engineering Center is being widely used. We are naturally pleased at this recognition of the carbon filter, but we are aware that it possesses shortcomings as a sampling device and that it must be supplemented by other techniques. Perhaps the greatest drawback in any device using carbon for sampling purposes is the difficulty with which many adsorbed organics are released. Beyond this, there is the enormous problem faced by the organic chemists charged with the responsibility of resolving complex "gunk" into its component compounds.

I should not leave this subject of monitoring water quality without reference to our failure to date to utilize effectively the biological indicators of pollution. Aquatic biologists insist that aquatic life is very sensitive to changes in water quality and they urge us to learn how to use these indicators. However, to date our use of biological indicators of pollution is relatively crude and expensive.

It must be re-emphasized that collection of data is not important if they do not relate to water quality. The time is ripe for close, critical scrutiny of the kind of information now being recorded in water quality basic data programs.

Can we effectively treat polluted water for reuse?

The main function of the modern water treatment plant is to remove particles suspended in the water, and to destroy microorganisms that manage to survive flocculation and filtration procedures. Except for removal of hardness, little attempt is made to remove soluble chemicals in drinking water. Where taste and odor are highly objectionable, carbon is usually applied. But carbon is selective in its action, and sometimes it is ineffective. We actually know little about the principle of adsorption as it applies to the use of carbon. Moreover, there is no assurance that harmful substances in solution will signify their presence by producing taste and odor. Here, as in waste treatment, interesting research opportunities exist.

Let me summarize my evaluation. I have considered the following water quality protection techniques:

1. Accounting for all pollution reaching a body of water.
2. Predicting the pollutional effects of a given waste.
3. Treating waste to prevent pollution.
4. Using the stream effectively and economically in waste disposal.
5. Monitoring the receiving stream intelligently.
6. Treating contaminated water for reuse effectively and economically.

In my opinion, these steps encompass all measures necessary to a sound control of water pollution. Mastery of these steps assures adequate protection of water quality. I would express my belief that the use of these techniques falls short of mastery.

I should like to point out that difficulty in separating polluting substances from water is a weakness common to many of the basic techniques in water quality protection. It is particularly apparent in chemical characterization of complex wastes, in treatment of wastes and water, and in monitoring receiving waters.

It is timely that we aggressively advance the development of new separatory techniques. In doing this we should note carefully the contributions the physical chemists may make to our field. Of particular interest are developments in modified adsorption, chromatography, foam fractionation, freezing, direct solvent extraction, and ion exchange. These by no means exhaust the list of physical chemical principles that may ultimately be applied with profit to the solution of our problems.

I have painted a somber picture in evaluating our ability to control water quality. I hope you understand that my evaluation was presented in a framework of research. This was done because the problems I have discussed are more problems of the future than of the past and present, although here and there we have already encountered them.

We are faced with problems of great research challenge. We can face them with confidence.